What Does the Transverse Carpal Ligament Contribute to Carpal Stability?

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J Wrist Surg 2015;4:31–34.

Abstract

Background The transverse carpal ligament is well known for its involvement in carpal tunnel syndrome, and sectioning of this ligament remains the definite treatment for this pathology. Some authors believe that the transverse carpal ligament is an important stabilizer of the carpal arch, whereas others do not consider it to be significant. Several studies have been performed, both in vivo and in in vitro. Sectioning of the transverse carpal ligament does not seem to have any effect on the width of the carpal arch in the unloaded condition. However, patients will load the arch during their activities of daily living.

Materials and Methods A cadaveric study was done with distraction of the carpal bones before and after sectioning the transverse carpal ligament.

Results With the transverse carpal ligament intact, the carpal arch is mobile, with distraction leading up to 50% widening of the arch. Sectioning of the transverse carpal ligament resulted in a significant widening of the carpal arch by a further 30%.

Conclusions Loading of the carpal arch after sectioning of the transeverse carapal ligament leads to a significant increase in intracarpal mobility. This will inevitably influence carpal kinematics in the patient and might be responsible for some complications after simple carpal tunnel releases, such as pillar pain, palmar tenderness, and loss of grip strength.

Keywords

- transverse carpal ligament
- flexor retinaculum
- carpal tunnel release
- carpal stability
- carpal tunnel syndrome

The terms *transverse carpal ligament* and *flexor retinaculum* have commonly been used to describe the fibrous structure running between the ulnar-sided hamate and pisiform bones and the radial-sided scaphoid and trapezium bones. However, the flexor retinaculum is composed of three parts. The most proximal part is continuous with the volar antebrachial fascia, the intermediate part is recognized as the transverse carpal ligament proper, and the distal part corresponds to the fibrous structure between the thenar and hypothenar eminences.[1] Histological examination and magnetic resonance imaging (MRI) show that the transverse carpal ligament consists of two clearly distinguished fibrous structures. The most superficial structure is in continuity with the antebrachial fascia, and a second, thicker layer is located deeper between the hamate and the scaphoid.[2] As the flexor retinaculum does not correspond to a specific autonomous structure, it has been suggested that the term *transverse carpal ligament* (TCL) should be used.[2]

The TCL acts as a pulley to prevent bowstringing of the flexor tendons and to promote economy and efficiency in finger flexion.[3–5]

The importance of the TCL for carpal stability and the effect of surgically sectioning this ligament are still controversial.[6–9]

The transverse carpal arch is not rigid, but allows some rotational movement between the bones of the distal carpal

DOI http://dx.doi.org/10.1055/s-0034-1398486.
ISSN 2163-3916.

row.[10–13] Many factors contribute to carpal stability: congruency between carpal bones, transcarpal tendons, negative intra-articular pressure, and interosseous, intrinsic, and extrinsic ligaments.[14–24] Some authors believe that the transverse carpal ligament is an important stabilizer of the carpal arch,[6,9] whereas others do not consider it to be significant.[7,8]

We performed an in vitro study to evaluate the effect of sectioning all layers of the transverse carpal ligament on motion in the carpal arch.[5]

Methods

Sixteen fresh frozen specimens were used. The skin of the volar aspect of the wrist was removed, preserving further soft tissue coverage of the carpal bones, and an eyelet screw and Kirschner wire (K-wire) were drilled into the hook of the hamate and into the scaphoid. Fluoroscopy was used to evaluate correct placement of screws and K-wires (►**Fig. 1**).

A 30newton static load was applied orthogonally to both eyelet screws, using a cable system and two 30-N weights, to distract the hamate and the scaphoid. The amount of weight was determined during the pilot study, aiming to produce a noticeable distraction without pullout of the screws or failure of the carpal ligament. The flexor tendons were left in situ, and no load was applied to the tendons. The authors wanted to preserve all other soft tissues covering the carpal bones to isolate the effect of sectioning the predetermined structures. The flexor tendons were not loaded, as the authors did not consider this to affect the results of the study. A caliper (Mitutoyo, Japan, accuracy 0.05 mm) was used to measure the distance between the K-wires at different steps of sectioning the transverse carpal ligament. The K-wires were marked at their point of entry into the hamate (Kh) and the scaphoid (Ks) and at a distance of 50 mm from the insertion point (Lh and Ls). Lh and Ls were used to amplify and validate the results. The measurements were performed at 0.1 mm precision. First the measurements were taken with an intact transverse carpal ligament, and then subsequently after sectioning one-third of the ligament up to complete rupture. The total length of the ligament was determined before testing with the same caliper, and the one-third intervals were calculated for each individual specimen. After this the palmar scapholunate (SL) and long radiolunate (LRL) ligaments were sectioned, followed by the radioscapholunate (RSL) ligament, in order to quantify the influence of these ligaments on carpal stability. Thus, there were seven experimental steps in total (►**Table 1**). In every step, 60 seconds were allowed for the soft tissues to adjust, before the measurements were done. All measurements were performed three times by three independent observers. No intraobserver agreement was obtained. The total distraction time in each specimen was ~15 minutes.

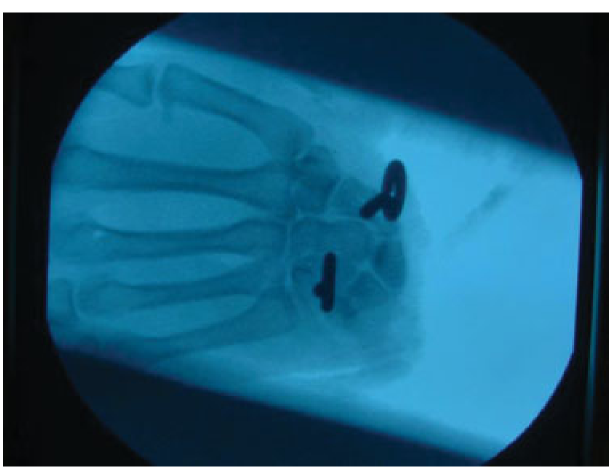

Fig. 1 Correct positioning of the screws was evaluated on postexperimental fluoroscopic images. The K-wires have already been removed. (Reproduced with permission from Tengrootenhuysen M, van Riet R, Pimontel P, Bortier H, Van Glabbeek F. The role of the transverse carpal ligament in carpal stability: an in vitro study. Acta Orthop Belg 2009;75(4):467–47.)

Results

The results are summarized in ►**Table 2**. On average, loading of the intact TCL showed an increase in the distal intercarpal distance of 55.3%. Sectioning of the TCL significantly increased this distance by 32.9% ($p < 0.05$). No significant difference was found between measurements performed following sectioning of the SL, LRL, and RSL ligaments.

Discussion

Fisk[6] was the first to look at the effect of sectioning the TCL on carpal stability. He reviewed 45 patients after unilateral release of the carpal tunnel. A tunnel view of both wrists was performed, and the distance was measured between the scaphoid and the pisiform. In 40 cases there was an increase in distance, ranging from 1 mm to 8 mm. In four cases there was no difference. There was a decrease in distance in only one case.

Gartsman et al[9] published a study, comparing the transverse carpal arch diameters before and after release of the carpal tunnel. The transverse diameter of the carpal arch was defined as the distance between the ridge of the trapezium and the hook of the hamate on carpal tunnel views of the wrist. They stated that sectioning of the transverse carpal tunnel ligament caused a mean widening of the diameter of 10,4% or 2.7 mm. Garcia-Elias et al[25] also performed an in vivo study including 21 patients with carpal tunnel syndrome. Intraoperatively the investigators inserted one K-wire into the hook of the hamate and one K-wire into the trapezium to measure the carpal arch distance. Measurements were performed in neutral, flexion, and extension before and after carpal tunnel release. The distance increased, with an average of 11% after division of the transverse carpal ligament. Guo et al[26] set up a computational analysis of carpal biomechanics based on finite element modeling. They evaluated the relative change in location of the carpal bones and the contact pressures of the wrist while axially loading the wrist with 100 N. After division of the transverse carpal ligament, the carpal bones generally deviated more radially while loading. Also, the trapezium, trapezoid, and scaphoid shifted further

Table 1 Sequence of experimental steps 1 through 7

Step 1	Unloaded TCL
Step 2	Loaded TCL
Step 3	Loaded TCL + sectioned ⅓ of the TCL
Step 4	Loaded TCL + sectioned ⅔ of the TCL
Step 5	Loaded TCL + sectioned 3/3 of the TCL
Step 6	Loaded TCL + sectioned TCL + sectioning S-L, LRL
Step 7	Loaded TCL + sectioned TCL + section S-L, LRL, RSL ligaments

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Abbreviations: LRL, long radiolunate ligament; RSL, radioscapholunate; S-L, interosseous scapholunate ligament; TCL, transverse carpal ligament.

Table 2 Step-by-step changes in the mean absolute distance between the scaphoid and hamate bones

Steps	1	2	3	4	5	6	7
Mean distance Ks-Kh (SD) mm	27.8 (3.3)	30.1 (3.7)	30.5 (3.6)	31.0 (3.6)	31.5 (3.6)	32.0 (3.6)	32.1 (3.7)
Mean total increase Ks-Kh (%)	0	55.3	63.7	75.5	88.2	97.5	100
Stepwise increase Ks-Kh (%)		55.3	8.4	11.8	12.7	9.3	2.5
Mean total increase Ls-Lh (%)	0	51.7	60.9	74.1	85.6	96.2	100
Stepwise increase Ls-Lh (%)		51.7	9.2	13.2	11.5	10.6	3.8

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Distance was measured between the points of entry of two K-wires (Ks-Kh) inserted in both carpal bones. Consecutive changes in the distance are also expressed as percentages (%) of the final increase in the distance between Ks and Kh noted at step 7. The table also shows the results of similar measurements made between the other two landmarks on the K-wires, Ls and Lh.

toward the radius, and the hamate, triquetrum, and pisiform moved further toward the metacarpals.

Additionally, Ishiko and colleagues[27] examined the in vitro kinematics of the scaphoid during wrist deviation in six cadaver wrists. The kinematics altered considerably with an increase in scaphoid extension both in radial and ulnar deviation, and the authors concluded that these findings might contribute to the development of postoperative symptoms such as pillar pain and palmar tenderness.

Finally, two papers[28,29] were published in the early 1990s, using MRI to look at the effect of transverse carpal ligament sectioning on the bony carpal arch. The carpal arch width was measured on MRI before and after carpal tunnel release. They both concluded that the postoperative volumetric increase was due to anterior displacement of the newly formed transverse carpal ligament, without any widening of the bony carpal arch.

Most recently, Xiu et al[13] investigated the structural mechanics of the transverse carpal arch in cadaver specimens in more detail. They compared the effect of compression and distraction on the proximal and distal part of the carpal tunnel, using sequential loading going from 2 to 10 N. They found that the proximal part of the carpal tunnel is more flexible than the distal part, and that the compliance is greater under compression than distraction. They found a significant arch width change aftter transverse carpal ligament transection in the proximal part of the carpal tunnel starting from a 2 N distraction force. The effect of transverse carpal ligament transection on the distal part was similar, but delayed and less pronounced.

The effect of sectioning the ligament has been investigated in different ways, and therefore the results are sometimes contradictory. The in vivo studies in which the carpal tunnel view on radiographs was used to compare the carpal arch pre- and postoperatively showed a widening of the carpal arch.[6,9] On the contrary, when MRI was used to determine the effect of transverse carpal ligament sectioning in vivo, no widening on the bony carpal arch was found.[28,29] In our study, we used cadaver wrists, and the hamate and scaphoid were distracted during testing. The carpal arch was already quite mobile (50% increase) with an intact transverse carpal ligament, and the carpal arch opened up further after progressive sectioning of the ligament (30% increase after total sectioning of the TCL). Nevertheless, the carpal arch still retained reasonable intrinsic stability without the TCL. The SL, LRL, and RSL did not contribute significantly to the carpal arch stability.[5]

Acknowledgments

We thank M. Tengrootenhuyzen M.D., P. Pimontel M.D., H. Bortier M.D., Ph.D., and F. Van Glabbeek M.D., Ph.D. for their contribution in the original study, which was partly presented in this paper.

Note
This work was performed at the Department of Orthopedic Surgery, Monica Hospital, Stevenslei 20, 2100 Antwerp, Belgium.

Conflict of Interest
None

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